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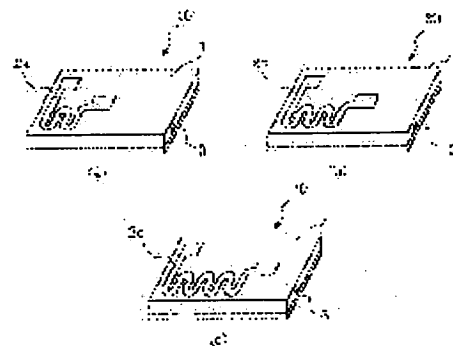
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(54) MICROPLASMA JET GENERATOR

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a microplasma jet generator capable of excellently producing stable microplasma jet by small electric power in a very small space under the atmospheric pressure.

SOLUTION: This microplasma jet generator to produce inductively coupled microplasma jet driven by a high frequency power supply in a VHF band has a substrate 1 is equipped with micro antennas 2a, 2b, 2c, a discharge tube 3 installed in the vicinity of the micro antennas, and the micro antenna has a wavy shape of a plurality of rolls.



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CLAIMS

[Claim(s)]

[Claim 1]

The microplasma jet generator characterized by having a substrate, the micro antenna arranged on this substrate, and the discharge tube installed near this micro antenna in the microplasma jet generator which generates the micro inductive-coupling plasma jet driven by the RF generator of a VHF band, and said micro antenna having the wavelike gestalt of two or more volumes in plate-like.

[Claim 2]

The microplasma jet generator according to claim 1 with which said micro antenna is arranged in the microplasma jet generation side edge section of a substrate by approaching.

[Claim 3]

The microplasma jet generator according to claim 1 or 2 with which plating of copper, gold, platinum, or these cascade screens is performed to said micro antenna.

[Claim 4]

Said plating thickness is a degree type,
 $\delta = (2 / (\omega \mu \sigma))^{1/2}$

the conductor which is expressed with (the inside of a formula and sigma are [permeability and omega of metaled conductivity and mu] the angular frequency of a RF) and with which the high frequency current flows -- the microplasma jet generator according to claim 3 which is twice [more than] the depth (delta) from a front face.

[Claim 5]

It is a microplasma jet generator given in any 1 term among claims 1-4 chosen from the group which said substrate ingredient becomes from an alumina, sapphire, aluminite RAIDO, silicon nitride, boron nitride, and silicon carbide.

[Claim 6]

The microplasma jet generator according to claim 5 said whose substrate ingredient is an alumina.

[Claim 7]

It is a microplasma jet generator given in any 1 term among claims 1-6 equipped with the high-voltage transformer assembly.

[Claim 8]

The generation method of the microplasma jet characterized by introducing plasma gas into a microplasma jet generator given in any 1 term by flow rate 0.05-5slm, and impressing the high frequency of a VHF band to a micro antenna among claims 1-7.

[Claim 9]

The micro chemical-analysis approach characterized by using a microplasma jet generator given in any 1 term among claims 1-7.

[Claim 10]

The micro chemical-analysis approach according to claim 9 using micro capillary electrophoresis.

[Claim 11]

Processing and the surface treatment approach characterized by using a microplasma jet generator given in any 1 term among claims 1-7.

[Claim 12]

Processing and the surface art according to claim 11 said whose processing and surface preparation are fusing of a partial part, etching, thin film deposition, washing, or hydrophilization processings of a workpiece.

[Claim 13]

Processing and the surface treatment approach according to claim 11 or 12 which approached the source of microplasma jet of said microplasma jet generator, and was equipped with the introductory device of reactant gas.

[Claim 14]

Processing and the surface treatment approach according to claim 13 chosen from the group which said reactant gas becomes from oxygen, nitrogen, air, and carbon fluoride and 6 sulfur fluorides.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[Field of the Invention]

[0001]

About a microplasma jet generator, in detail, this invention makes microplasma jet generate good with an atmospheric pressure, and processing and surface treatment, such as fusing, etching, and thin film deposition, can be performed to the partial part of a workpiece at high speed, and it relates also to a micro chemical-analysis system (Micro Total Analysis System) ("muTAS" is called hereafter) at a useful microplasma jet generator.

[Background of the Invention]

[0002]

Conventionally, plasma jet is made useful performing processing and surface treatment, such as fusing, etching, and thin film deposition, to a workpiece, and high temperature processing of harmful matter etc. is used in other various fields.

[0003]

In order to generate minute plasma jet with a current and a diameter of 2mm or less about such plasma jet, the approach using DC arc discharge is learned well. However, the approach using DC arc discharge has various problems, like that an electrode tends to deteriorate, that use of reactant gas cannot be performed, and a work material is limited to a conductor.

[0004]

On the other hand, the microplasma jet generator attracts attention very much from practical application sides, such as a plasma display panel (PDP), and the application to process units, such as processing, surface treatment, etc., such as an analysis apparatus in the field of chemistry and biochemical analysis and a microchip used for a micro device, is also expected further in recent years.

[0005]

It especially sets in the field of chemistry and biochemical analysis. Silicon, glass, The flow mold analysis system which carries out micro processing of the slot of dozens of micrometer width of face, and performs high-speed separation of ultralow volume matter, such as a gas chromatography (GC) and micro capillary electrophoresis (muCE), is formed on chips, such as plastics. It combines with the on-chip high sensitivity detection approaches, such as laser induction firefly photodetection and electrochemistry measurement using microelectrode, research of muTAS which realizes innovative high performance analysis is progressing quickly, and application in a broad field, such as a gene analysis, a medical inspection, and new drug development, is expected.

[0006]

Moreover, by the bench top's analysis apparatus, the high speed and the overly high sensitivity matter detection approach of having combined the inductively coupled plasma-atomic emission spectroscopy (ICP-OES: Inductively Coupled Plasma Optical Emission Spectroscopy) known by separation technology, such as capillary electrophoresis, as an elemental-analysis method sensibility is very high, and ICP mass analysis are developed in recent years. Then, it is possible to make a high density microplasma generate on chips, such as glass, to pile up muTAS, and to apply as a high sensitivity detection module.

[0007]

The report of the beginning of the microplasma chip for analysis is released in 1999 for the purpose of the atom in GC (gas chromatography) which turned muTAS by A. Manz and others, and molecule detection. In minute space with a width-of-face [of 450 micrometers] x depth [of 200 micrometers] x die length of 2000 micrometers formed in the glass chip, the direct-current glow discharge of helium was generated with 10-50mW power under reduced pressure of about 17 kPa(s), and 600 ppm of limit of detection of methane are estimated. Although it became discharge impossible by the spatter of a cathode electrode in 2 hours, with atmospheric pressure, it is reported after that by the actuation under reduced pressure that actuation of 24 hours is also possible.

[0008]

Moreover, the 2.45GHz microwave discharge chip using a microstrip antenna is reported as first microplasma chip which operates with an atmospheric pressure and a non-electrode, the discharge interior of a room with a depth [of 0.9mm] x width-of-face [of 1mm] x die length of 90mm is made to generate discharge with a die length of 2-3cm in 10-40W, and 10 ng(s)/ml is reported as limit of detection of mercury vapour.

[0009]

However, since it is not easy to generate the stable high density plasma in minute space with small power, implementation of making possible the high sensitivity microanalysis by implementation of the microplasma to muTAS chip has been made impossible.

[0010]

It succeeded in this invention person proposing muTAS using the source of VHF drive micro inductively coupled plasma using a microplasma previously, and opening the way of a microanalysis [high sensitivity by this] in such a situation, (patent reference 1). The source of VHF drive micro inductively coupled plasma indicated in this patent reference 1 is the microplasma chip 110 which possesses the discharge tube 103 and the one-roll monotonous mold antenna 102 in the substrate 101 center made from the quartz of 30mm angle as shown in drawing 10. This microplasma chip 110 is driven by the RF generator of a VHF band, introduces plasma gas 104 from one side of the discharge tube 103, and makes the microplasma jet 105 generate from another side.

[Patent reference 1] JP,2002-257785,A (a claim, [drawing 1], etc.)

[Description of the Invention]

[Problem(s) to be Solved by the Invention]

[0011]

Although the high sensitivity microanalysis in muTAS became possible by the source of VHF drive micro inductively coupled plasma reported to the above-mentioned patent reference 1, about the microplasma jet generator, improvement in the further engine performance is desired from the usefulness.

[0012]

Then, the purpose of this invention is more than the former to offer the microplasma jet generator which can make the stable microplasma jet in minute space generate good with small power with an atmospheric pressure.

[Means for Solving the Problem]

[0013]

In order to solve the above-mentioned technical problem, in the microplasma jet generator which generates the micro inductive-coupling plasma jet driven by the RF generator of a VHF band, the microplasma jet generator of this invention is equipped with a substrate, the micro antenna arranged on this substrate, and the discharge tube installed near this micro antenna, and is characterized by said micro antenna having the wavelike gestalt of two or more volumes in plate-like.

[0014]

Moreover, this invention is the generation method of the microplasma jet characterized by introducing plasma gas into said microplasma jet generator by flow rate 0.05-5slm, and impressing the high frequency of a VHF band to a micro antenna.

[0015]

It can be stabilized with small power and the inductive-coupling method using the induction field produced according to the current which flows at an antenna can be made to generate high density plasma jet by supplying power to plasma gas efficiently rather than the capacity-coupling method which uses the VHF band which can catch some of ion and electrons in the thin discharge tube in this invention, and accelerates an electron by electrostatic field.

[Effect of the Invention]

[0016]

As for the microplasma section, according to the equipment and the approach of this invention, it is possible to originate in power flux density becoming high in inverse proportion to the discharge volume, and for it to be stabilized and to also make the small power of dozens W generate the plasma jet of high density extremely in an atmospheric pressure.

[0017]

Moreover, since it not only can miniaturize itself, but power required for a drive becomes 1/10 or less as compared with about 1kW of bench top mold equipment, the equipment of this invention leads to the miniaturization of an RF generator, and is advantageous to lightweight-izing of the whole equipment. Furthermore, since the consumption of gas also becoming sharply reducible and water cooling become unnecessary, carrying-ization of the whole system is attained. It becomes possible with the miniaturization of such a whole system to perform processing and surface treatment of more detailed etching, thin film deposition, etc.

[Best Mode of Carrying Out the Invention]

[0018]

Hereafter, 1 operation gestalt of this invention is concretely explained with reference to a drawing.

Drawing 1 (a) Each microplasma jet generators (it is hereafter written as a "plasma chip") 10, 20, and 30 shown in - (c) are equipped with a substrate 1, micro antenna 2a arranged on the substrate 1, 2b and 2c ((a) of drawing 1 two volumes and (b) three volumes and (c) four volumes), and the discharge tube 3 installed by the substrate 1, respectively. In this invention, it is important that this micro antenna 2a, 2b, and 2c have two or more 2-4 wavelike gestalten of four volumes more preferably in plate-like. By considering as the micro antenna of this wavelike gestalt, it compares with the plasma chip which has the wavelike gestalt of one volume of patent reference 1 publication, and it is markedly alike, the effectiveness improves, and it becomes possible under an atmospheric pressure to make the microplasma jet stabilized in minute space generate very good.

[0019]

Here, as shown in drawing 1 (a) - (c), as for micro antenna 2a, 2b, and 2c, it is desirable to be approached and arranged in the microplasma jet generation side edge section of a substrate 1. This reason is because it becomes higher-density, so that the electron density distribution of the plasma which drove by the RF generator of a VHF band and was generated approaches a micro antenna. In addition, the electron density distribution of the plasma is computable from Stark broadening of Hbeta luminescence line breadth of the hydrogen slightly added in the plasma.

[0020]

moreover, micro antenna 2a, 2b, and 2c -- a conductive metal -- plating of copper, gold, platinum, or these cascade screens gives preferably -- having -- **** -- the plating thickness -- a degree type,
 $\delta = (2 / (\omega \mu \sigma))^{1/2}$

the conductor which is expressed with (the inside of a formula and sigma are [permeability and omega of metaled conductivity and mu] the angular frequency of a RF) and with which the high frequency current flows -- it is desirable to make it into twice [more than] the depth (delta) from a front face, for example, it serves as critical thickness with the actual thickness of about 100 micrometers by 100MHz by coppering.

[0021]

Furthermore, when it is stabilized and high density plasma jet is made to generate, the wave-like wavelength of the micro antennas 2a-2c is 2-10mm preferably, and a size (width of face) is 0.5-2mm preferably.

[0022]

Moreover, in this invention, as for the ingredient of a substrate 1, it is desirable that thermal conductivity is an insulating material highly, for example, an alumina, sapphire, aluminite RAIDO, silicon nitride, boron nitride, silicon carbide, etc. can be mentioned suitably, and it is an alumina especially preferably.

[0023]

Furthermore, as for the discharge tube 3 installed near the micro antenna 2a - 2c, it is desirable that the substrate is installed directly under the wavelike gestalt part of the micro antennas 2a-2c. However, the discharge tube 3 can change the location which does not always need to be one and is suitably installed according to the use application of a microplasma with the plasma chips 10, 20, and 30. The tubing cross-sectional area of the discharge tube 3 is 2 0.01-10mm preferably, when making high density plasma jet stabilize and generate.

[0024]

The plasma chip of above-mentioned this invention can be manufactured by adopting the known photolithography

method etc. This production process is explained based on drawing 2. First, as shown in (a), the resist mask 5 which has the opening 4 of a micro antenna configuration is formed on a substrate 1. Subsequently, as shown in (b), the metallic material 6 which forms a micro antenna in the shape of a substrate by RF magnetron sputtering is plated, and a chromium layer is preferably prepared as a glue line if needed in this case. Subsequently, as shown in (c), it leaves the metal layer 6 of an antenna configuration by lift off, and the antenna configuration section is formed in desired thickness by electrolytic plating. As shown in (d), in order to stop the discharge tube 3 after that, a substrate and the plate 7 of the same ingredient are pasted up on the rear face of a substrate 1.

[0025]

The insulating tubes, such as alumina tubing, are stuck on the substrate in which the micro antenna other than a **** was formed, and the formation approach of the discharge tube can also be arranged.

[0026]

the plasma chip formed as mentioned above -- a flow rate -- by introducing the plasma gas of 0.5–2slm preferably, and impressing the RF of a VHF band to a micro antenna through a matching circuit 0.05 to 5 slm, from the RF generator (high-voltage transformer assembly) of VHF, it is stabilized and plasma jet can be generated. As plasma gas which can be used, an argon, neon, and helium can be mentioned suitably and confusion gas with these gas, hydrogen, oxygen, or nitrogen can also be used.

[0027]

The equipment and the approach of this invention can be used suitable for the micro chemical analysis which uses the micro chemical-analysis approach, especially micro capillary electrophoresis.

[0028]

Furthermore, the equipment and the approach of this invention can be used suitable for processing and the surface-preparation approach of fusing of processing and the surface-preparation approach, especially the partial part of a workpiece, etching, thin film deposition, washing, or hydrophilization processing.

[0029]

Moreover, in processing and the surface-preparation approach using the microplasma jet generator of this invention, the source of microplasma jet is approached, the introductory device of reactant gas is needed, and the reactant gas is oxygen, nitrogen, air, and carbon fluoride and 6 sulfur fluorides preferably. Reactant gas can be supplied by preparing a ring-like nozzle near the outlet of the source of the plasma.

[0030]

For example, in case silicon wafer etching is performed, even if it approaches a substrate too much and leaves the source of the plasma too much, it is in the inclination for the etching depth to become shallow. Moreover, the etching depth becomes deep as the flow rate of reactant gas increases, but if a certain flow rate more than fixed is exceeded, the plasma will be extinguished and the etching depth will decrease. Furthermore, although the almost same etch rate as the case where it fixes also when the source of the plasma is scanned can be obtained, if a certain fixed rate is exceeded, the inclination for an etch rate to decrease will be seen. This is considered for the effectiveness of local heating of the substrate by the plasma to influence etching.

[Example]

[0031]

Hereafter, this invention is explained based on an example.

The example 1 of manufacture

The plasma chip was manufactured according to the production process shown in drawing 2. First, the number of turns of a micro antenna formed the resist mask 5 which has the opening 4 of the micro antenna configuration of two round trips on the alumina substrate (15mm by 30mm) 1 at the process shown in drawing 2 (a). Under the present circumstances, the opening 4 of a micro antenna configuration was made to approach the micro jet generation side edge section of a plasma chip, and was formed. Thereby, the high density plasma near the plasma antenna can be used in the condition of having made it generating in the shape of jet from a microchip. In addition, the crevice for the discharge tubes (1mm[1mm by] x die length of 30mm) was beforehand formed in the rear face of a substrate 1.

[0032]

Subsequently, about 1000Å of Cu(s) used as a seed layer [in / for Cr which serves as a glue line between substrate-Cu(s) by RF magnetron sputtering at the process shown in (b) / the process of about 500Å and next electrolysis Cu plating] was made to deposit. Next, it left the layer 6 of Cr-Cu to the antenna configuration section by lift off at the process shown in (c), and 50–200-micrometer Cu was made to deposit on the antenna configuration section by electrolysis Cu plating. In order to stop the discharge tube 3 finally at the process shown in (d), the alumina plate 7 was pasted up on the chip rear face, and the plasma chip was manufactured.

[0033]

The example 2 of manufacture

In the example 1 of manufacture, the plasma chip was manufactured like the example 1 of manufacture except having replaced the alumina substrate with the quartz substrate.

[0034]

The examples 3 and 4 of manufacture

Two sorts of plasma chips were manufactured like the example 1 of manufacture except having considered the number of turns of a micro antenna as the (b)3 round trip and the (c)4 round trip, as shown in (b) of drawing 1, and (c).

[0035]

The example 1 of a trial: The temperature-change trial of the micro antenna by the difference in a substrate ingredient. The radioactive difference when generating the plasma with Power 5W, 10W, 20W, and 50W was visualized by thermography (CPA made from FLIR- 7000), using respectively the plasma chip of the example 1 of manufacture, and the example 2 of manufacture. Consequently, also when it was any at the time of being a time of a substrate being a quartz, and an alumina, the temperature rise by Joule heating of the antenna section accompanying the increment in power was checked. Although the rapid temperature rise accompanying the increment in power was intensively checked near the antenna in the quartz substrate when the temperature distribution within a chip side were compared, it was checked in the alumina substrate that temperature rises to homogeneity mostly with the whole chip. This showed that the alumina substrate of heat dissipation nature was better than a quartz substrate.

[0036]

Drawing 3 is a graph which shows the relation of the power and the antenna temperature by the difference in the substrate ingredient of the plasma chip of the example 1 of manufacture, and the example 2 of manufacture. Compared

with the alumina substrate, the rise of a large antenna temperature was checked with the increment in a supply voltage in the direction of a quartz substrate. The power generally supplied to the plasma is a degree type,

$$P_{\text{plasma}} = (R_{\text{plasma}} / (R_{\text{plasma}} + R_{\text{system}})) (P_{\text{f}} - P_{\text{r}})$$

It is given with (the inside of a formula, P_{plasma} :plasma injection power, R_{plasma} :plasma resistance, R_{system} :system resistance, P_{f} :incidence power, and P_{r} :reflective power). Therefore, since the resistance increase by the temperature rise of the copper antenna by the temperature rise which requires for an antenna the direction of the plasma chip which used as the substrate the alumina which has about 15 times as many heat dissipation nature as a quartz is eased, it turns out that the direction of the plasma chip of an alumina substrate is suitable for the microplasma jet generator without a cooler style.

[0037]

The example 2 of a trial: Power dependence study of Ar luminescence reinforcement by the difference in a substrate ingredient

Drawing 4 is the mimetic diagram of the measuring device of argon luminescence reinforcement. The argon was introduced into the discharge tube 3 currently installed in the substrate 1 from tubing 8. Plasma P occurred by fluctuating power at a micro antenna and impressing a RF with a frequency of 144MHz to it using an RF generator and a matching circuit. Argon luminescence reinforcement was measured for the generated plasma P with the spectroscopy through the optical fiber 9. As a Measuring condition, the argon flow rate was set to 0.7slm(s), and the luminescence reinforcement of a 763nm ArI spectrum was measured from the micro antenna edge in the location of 2mm. Drawing 5 shows the relation between the power by the difference in the substrate ingredient of the plasma chip of the example 1 of manufacture, and the example 2 of manufacture, and argon luminescence reinforcement.

[0038]

Consequently, it turned out that luminescence reinforcement with the more expensive chip made from an alumina is obtained compared with the chip made from a quartz. This shows that an insulating material with thermal conductivity high as a substrate ingredient is desirable. Therefore, in subsequent experiments, the chip made from an alumina of the example 1 of manufacture was used.

[0039]

Example [of a Trial] 3: Thickness dependence study of Cu micro antenna of Ar luminescence reinforcement

The argon flow rate was set to the frequency of 144MHz, and supply-voltage 50W for [0.7slm(s) and charging-time-value] 10 minutes, and the luminescence reinforcement of an ArI spectrum (696nm, 706nm, 738nm, 750nm, 763nm, and 772nm) was measured from the antenna edge in the location of 2mm. Drawing 6 shows the argon luminescence reinforcement in the ArI spectrum of each wavelength, and the relation of the copper film thickness of an antenna.

[0040]

From drawing 6, when Cu thickness was set to 100 micrometers or less, it was checked that luminescence reinforcement falls also in which ArI luminescence line, and it was checked that every ArI luminescence reinforcement is saturated with thickness 100 micrometers or more. the high frequency current which flows at an antenna -- the skin effect -- a conductor -- since it cannot invade from a front face more than a certain depth (called a skin depth), even if it increases thickness, resistance of an antenna will not fall any longer. In not fulfilling this thickness, the effectiveness of power in which resistance of an antenna is supplied to increase and the plasma deteriorates. This experimental result showed that Cu thickness indispensable for the antenna in this model was about 100 micrometers.

[0041]

Example [of a Trial] 4: The aging trial of Ar luminescence reinforcement

The argon flow rate was set to 0.7slm(s) and supply-voltage 50W, and after making the condition of ordinary temperature to discharge start the inside of a matching circuit from an antenna edge in the location of 2mm, luminescence reinforcement of an ArI spectrum (696nm, 706nm, 738nm, 750nm, 763nm, and 772nm) was measured. Drawing 7 shows the argon luminescence reinforcement in the ArI spectrum of each wavelength, and the relation of a charging time value.

[0042]

Since the matching circuit which does not have a cooler style in this example of an experiment was used, each Ar luminescence reinforcement fell from the fall of plasma injection power for 5 minutes after discharge starting from drawing 7 by the rise of the thermal resistance by the temperature rise from Joule heating produced in the whole circuit, the temperature rise in a circuit was saturated after discharge-starting 5 minute and plasma injection power became fixed, it was checked that Ar luminescence reinforcement becomes fixed.

[0043]

Example [of a Trial] 5: Quantity-of-gas-flow dependence study of Ar luminescence reinforcement

It was referred to as supply-voltage 50W, and luminescence reinforcement of an ArI spectrum with a wavelength of 763nm was measured from the antenna edge in the location of 2mm. Drawing 8 shows argon luminescence reinforcement and the relation of an argon quantity of gas flow. Consequently, the maximum luminescence reinforcement was obtained near Ar quantity-of-gas-flow 0.7slm. Since supply will be possible with a small chemical cylinder if it is a quantity of gas flow of this amount, it is thought possible to carry out portability of the microplasma jet generator.

[0044]

The example 6 of a trial: Power dependence study of Ar luminescence reinforcement by the formation of a micro antenna form status change

The argon flow rate was set to 0.7slm(s), from the antenna edge, the number of turns of an antenna configuration were changed with 2, 3, and 4, and measurement of the luminescence reinforcement of an ArI spectrum with a wavelength of 763nm was performed in the location of 2mm, as shown in drawing 1. Drawing 9 shows the power dependency of Ar luminescence reinforcement when changing an antenna configuration.

[0045]

Consequently, when the antenna arranged in the discharge tube upper part was lengthened, it turned out that high luminescence reinforcement is obtained. However, when the number of turns of an antenna were 3 and 4, the rise of already not much big luminescence reinforcement, i.e., a plasma consistency, was not seen. Furthermore, when the antenna was lengthened too much, it was thought that loss of power became a problem, and therefore, the time of number of turns being 4 was judged to be the optimal antenna configuration.

[Availability on industry]

[0046]

Since the miniaturization of the microplasma jet generator of this invention is attained more than the former, in muTAS, especially, it demonstrates that a cellular phone is possible and the effectiveness excellent in the detection sensitivity to a minute amount sample, and can expect use to "spot analysis" of outbreak nature accident detection of harmful matter mixing in purification plant etc., the soil pollution analysis of industrial-liquid-waste contamination which is needed serially by monitoring, food poisoning, urgent analysis in a drug contamination accident site, and dealings in real estate. Moreover, also in use of processing and surface preparation, such as etching and thin film deposition, with the miniaturization of the equipment of this invention, it becomes easy to move the source of plasma jet itself, and detailed processing and surface preparation of it become possible from the former.

[Brief Description of the Drawings]

[0047]

[Drawing 1] the number of turns of an antenna -- (a)2 volume, (b)3 volume, and (c) -- it comes out and four volumes are the perspective views of each of a certain plasma chip.

[Drawing 2] It is process drawing of manufacture of a plasma chip.

[Drawing 3] It is the graph which shows the relation of the power and the antenna temperature by the difference in the substrate ingredient of a plasma chip.

[Drawing 4] It is the mimetic diagram showing the measuring method of argon luminescence reinforcement.

[Drawing 5] It is the graph which shows the relation of the power and argon luminescence reinforcement by the difference in the substrate ingredient of a plasma chip.

[Drawing 6] It is the graph which shows the relation of the argon luminescence reinforcement and the copper film thickness of an antenna in the ArI spectrum of each wavelength.

[Drawing 7] It is the graph which shows the relation of the argon luminescence reinforcement and the charging time value in the ArI spectrum of each wavelength.

[Drawing 8] It is the graph which shows the relation between argon luminescence reinforcement and an argon quantity of gas flow.

[Drawing 9] It is the graph which shows the relation between the number of turns of an antenna, and argon luminescence on-the-strength-power.

[Drawing 10] It is the perspective view of the conventional plasma chip.

[Description of Notations]

[0048]

1,101 Substrate

2a, 2b, 2c Micro antenna

3,103 Discharge tube

4 Opening

5 Resist Mask

6 Metal Layer (Metallic Material)

7 Plate

8 Tubing

9 Optical Fiber

10, 20, 30 Plasma chip

102 One-Roll Monotonous Mold Antenna

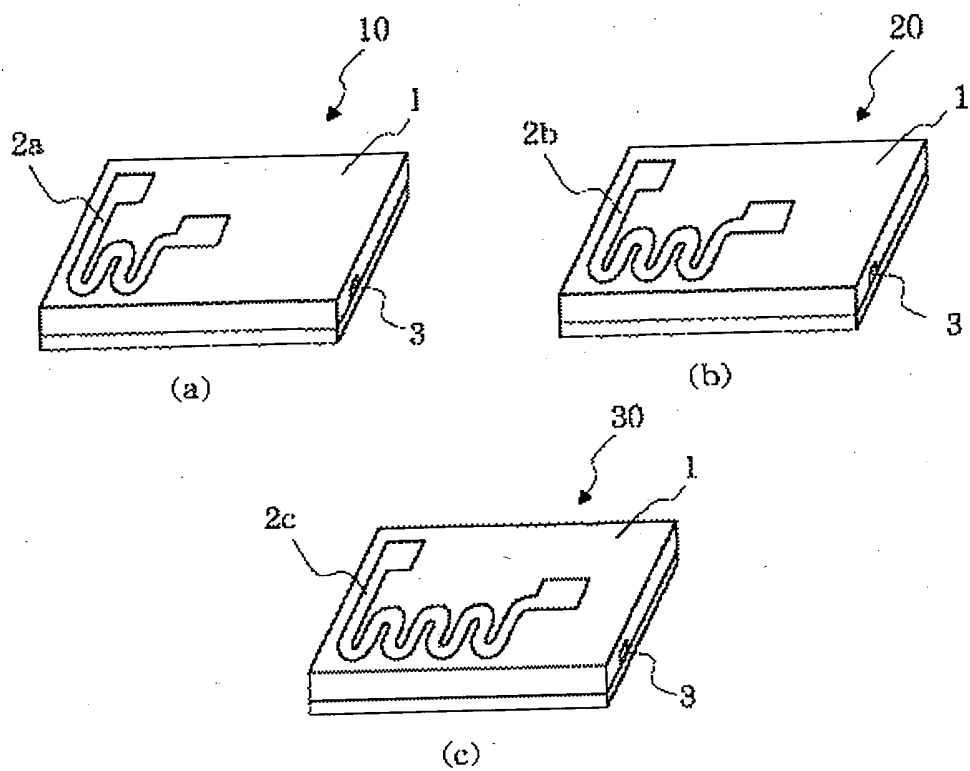
104 Plasma Gas

105 Microplasma Jet

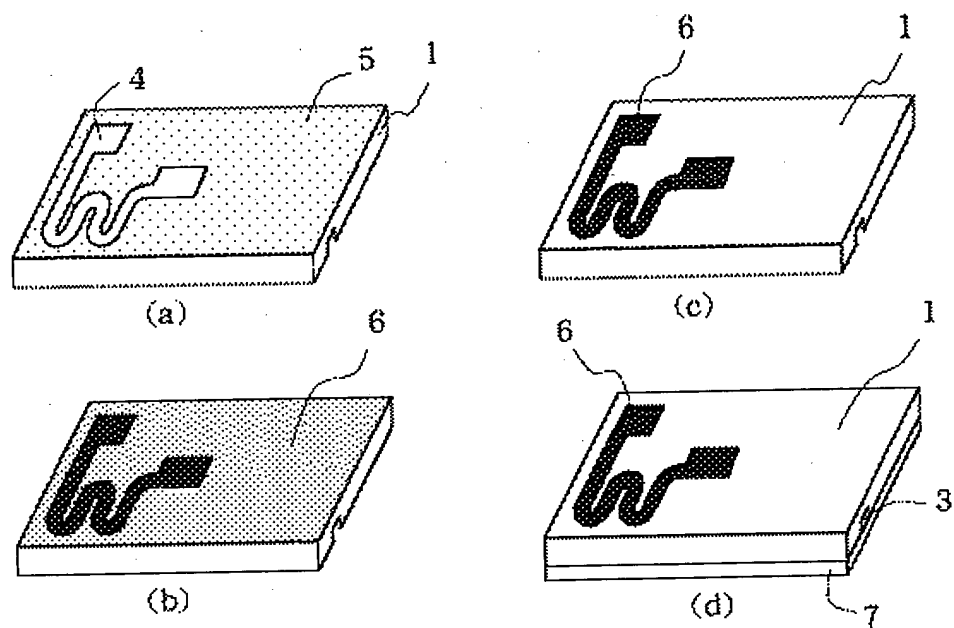
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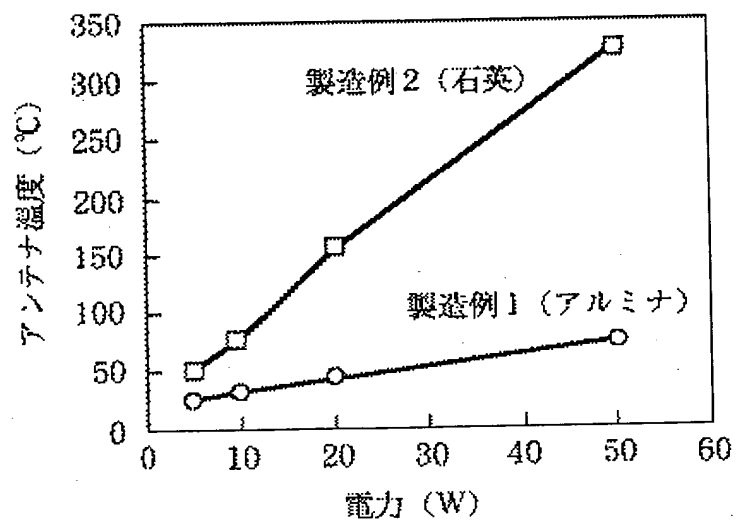
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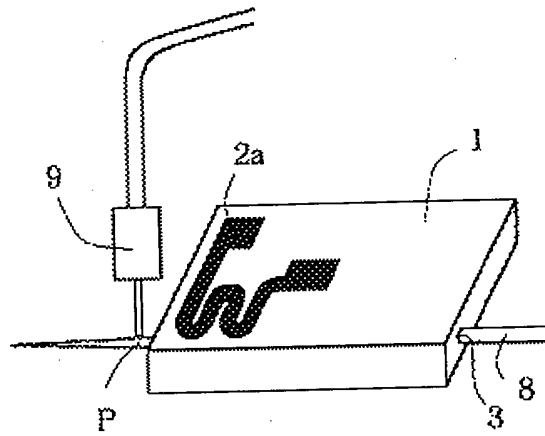
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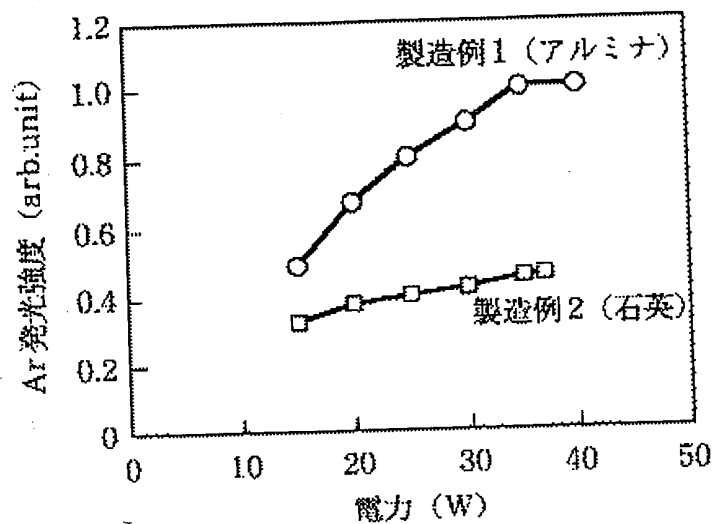
Drawing 3



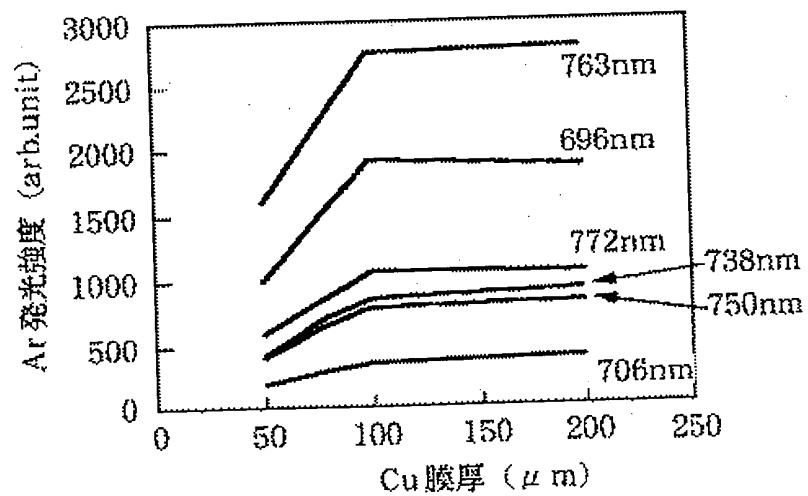
Drawing 4



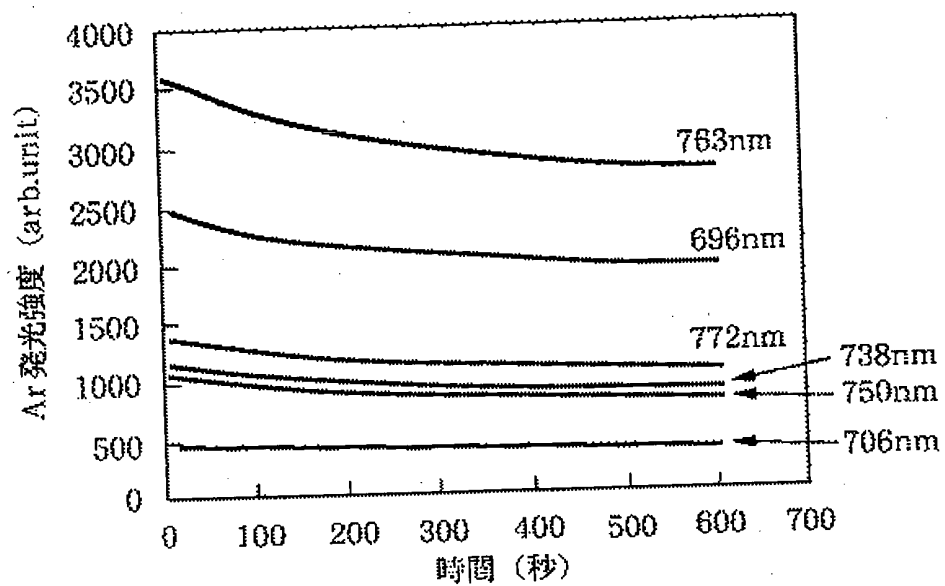
Drawing 5



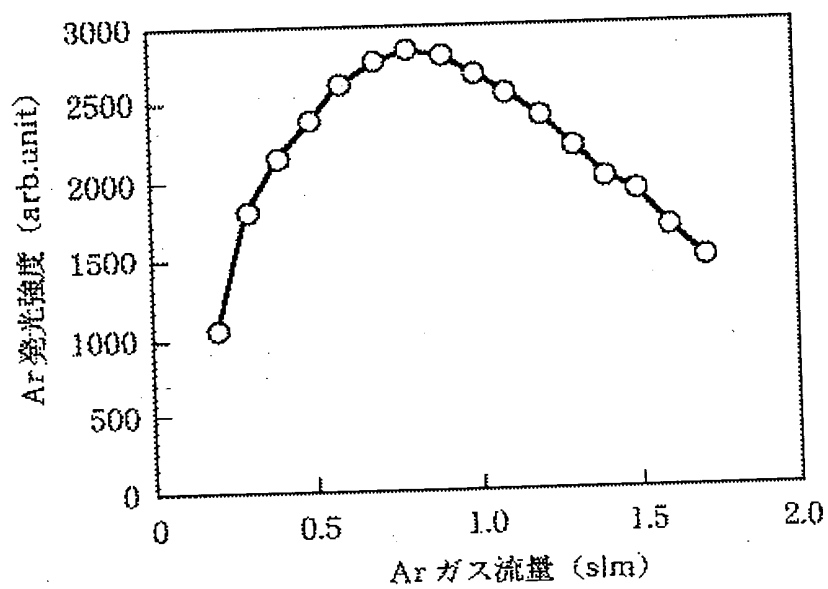
Drawing 6

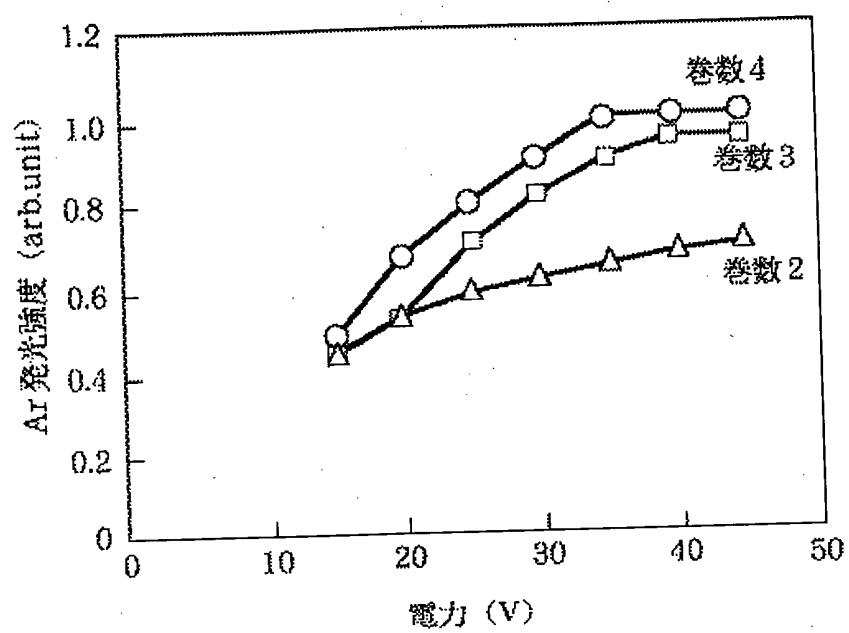


Drawing 7

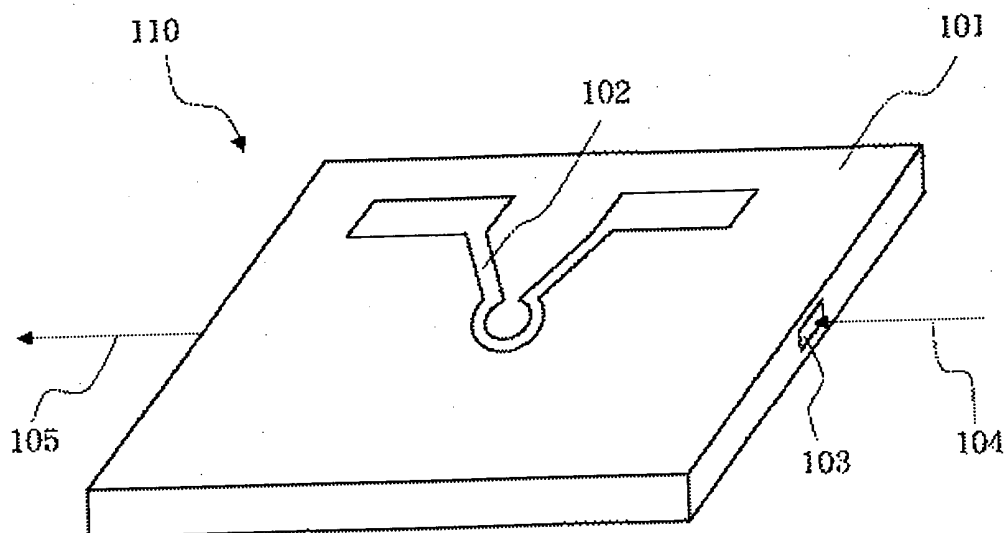


Drawing 8





Drawing 10



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